Aeroheating Test of CEV Entry Vehicle at Turbulent Conditions

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An investigation of the aeroheating environment of the Project Orion Crew Entry Vehicle has been performed in the Arnold Engineering Development Center Tunnel 9. Data were measured on a ~3.5% scale model (0.1778m/7-inch diam.) of the vehicle using coaxial thermocouples in the Mach 8 and Mach 10 nozzles of Tunnel 9. Runs were performed at free stream Reynolds numbers of 1×10^6/ft to 20×10^6/ft in the Mach 10 nozzle and 8×10^6/ft to 48×10^6/ft in the Mach 8 nozzle. The test gas in Tunnel 9 is pure N_2, which at these operating conditions remains un-dissociated and may be treated as a perfect gas. At these conditions, laminar, transitional, and turbulent flow was produced on the model at Mach 10, and transitional and turbulent conditions were produced on the model at Mach 8. The majority of runs were made on a clean, smooth-surface model configuration and a limited number of runs were made in which inserts with varying boundary-layer trips configurations were used to force the occurrence of transition. Laminar and turbulent predictions were generated for all wind tunnel test conditions and comparisons were performed with the data for the purpose of helping to define uncertainty margins for the computational method. Data from both the wind tunnel test and the computations are presented herein. Figure 1 shows a schematic of the thermocouple locations on the model and figures 2 and 3 show a photo and schematic of the AEDC Hypervelocity Tunnel 9. Figure 4 shows a typical grid used in the computations. From the comparisons shown in figures 5 through 8 it was concluded that for perfect-gas conditions, the computations could predict either fully-laminar or full-turbulent flow to within ±10% of the experimental data. The experimental data showed that transition began on the leeside of the heat-shield at a free stream Reynolds number of 9×10^6/ft in the Mach 10 nozzle and fully-developed turbulent flow was produced at 20×10^6/ft. In the Mach 8 nozzle, transition on the leeside of the heat-shield was observed for all test conditions, and full-developed turbulent flow occurred at a free stream Reynolds number of 18×10^6/ft. On the aftbody of the vehicle no evidence of turbulence was detected at Mach 10 conditions, and at Mach 8 conditions, transition appeared to begin on the windside of the atfbody at free stream Reynolds number of 18×10^6/ft with fully-developed turbulent flow occuring only at the highest test condition of 48×10^6/ft.

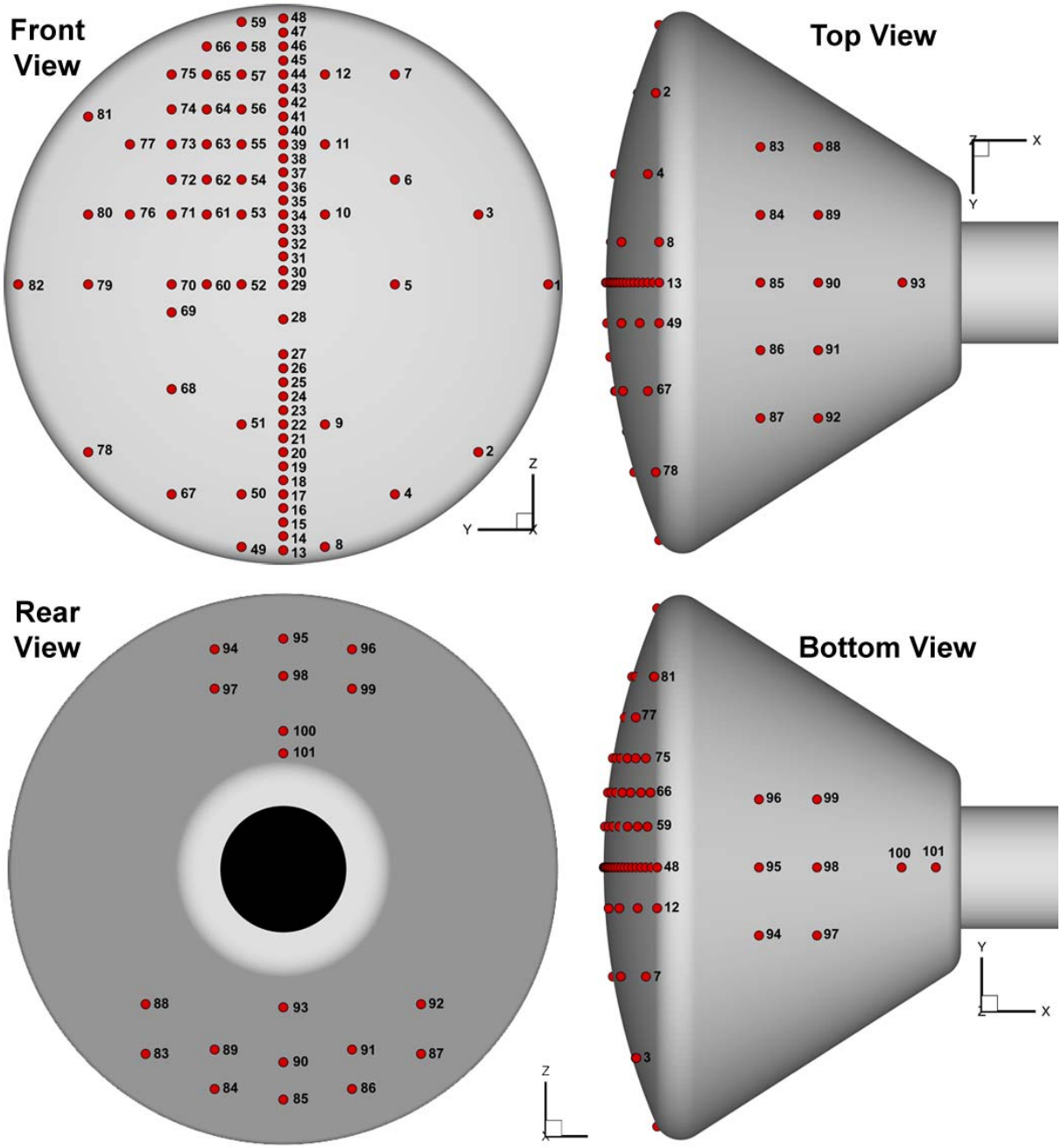

Figure 1. Thermocouple layout on CEV model

Figure 2. AEDC Hypervelocity Tunnel 9 (Mach 10 nozzle)

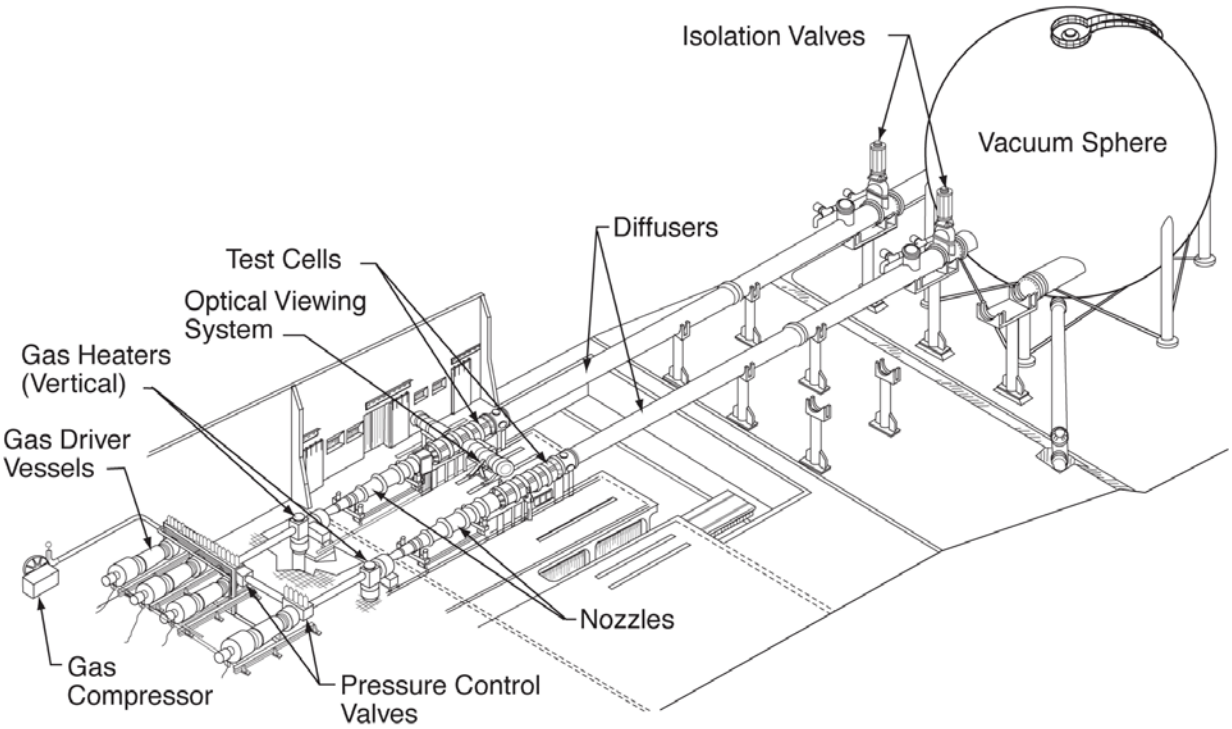

Figure 3. Schematic of AEDC Hypervelocity Tunnel 9

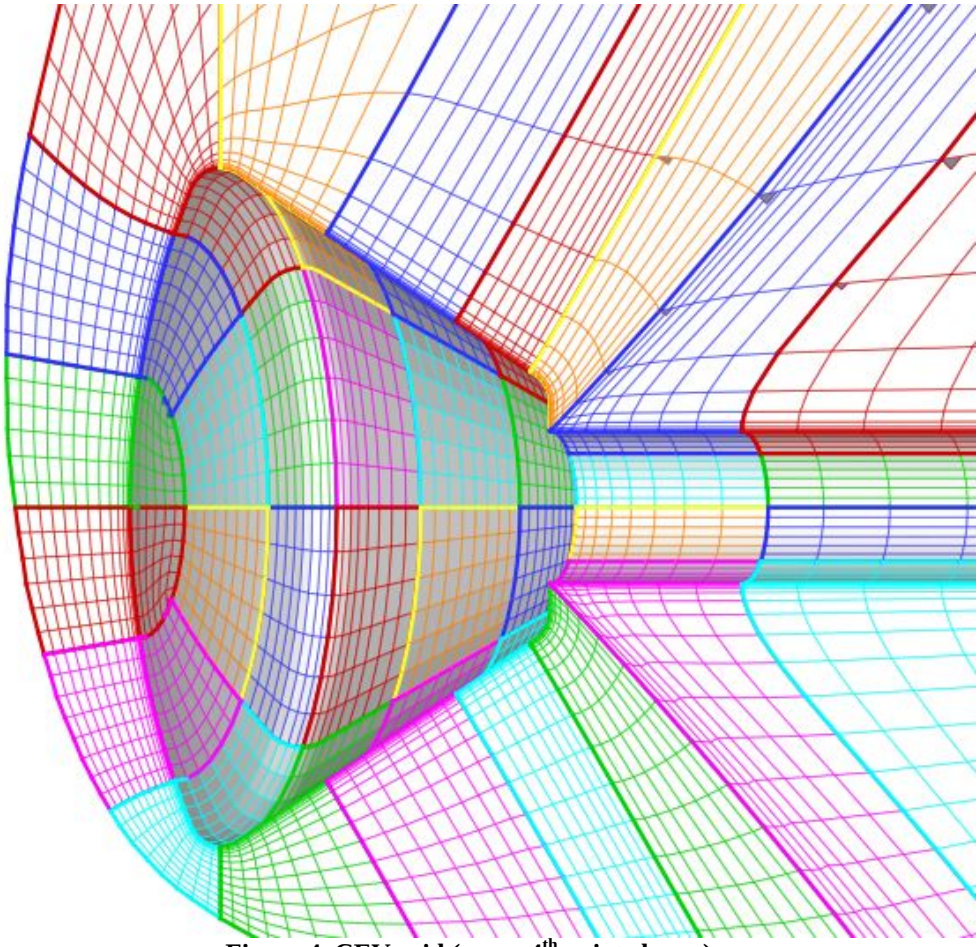

Figure 4. CEV grid (every 4th point shown)

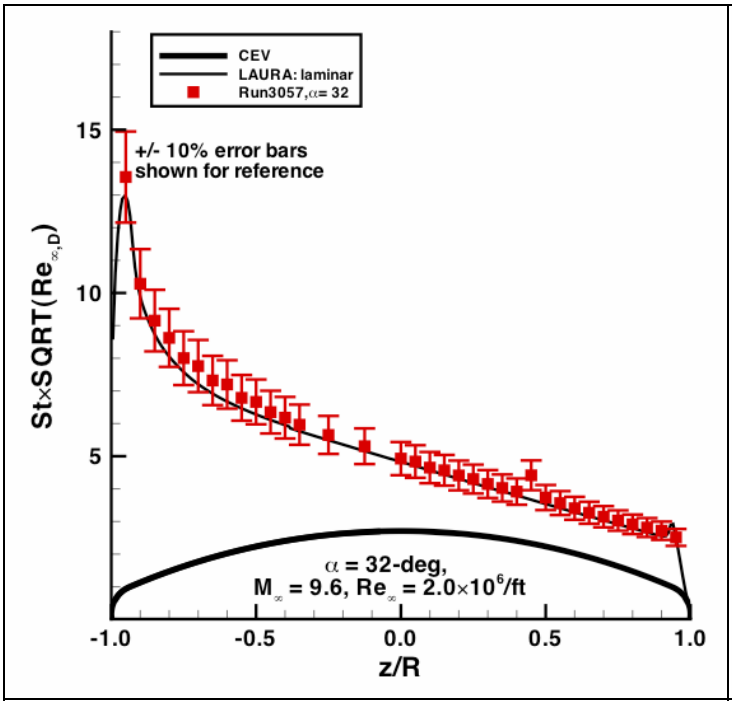

Figure 5. Comparison of forebody heating data with predictions, Mach = 10, Re = 2E6/ft, AoA = 28-deg

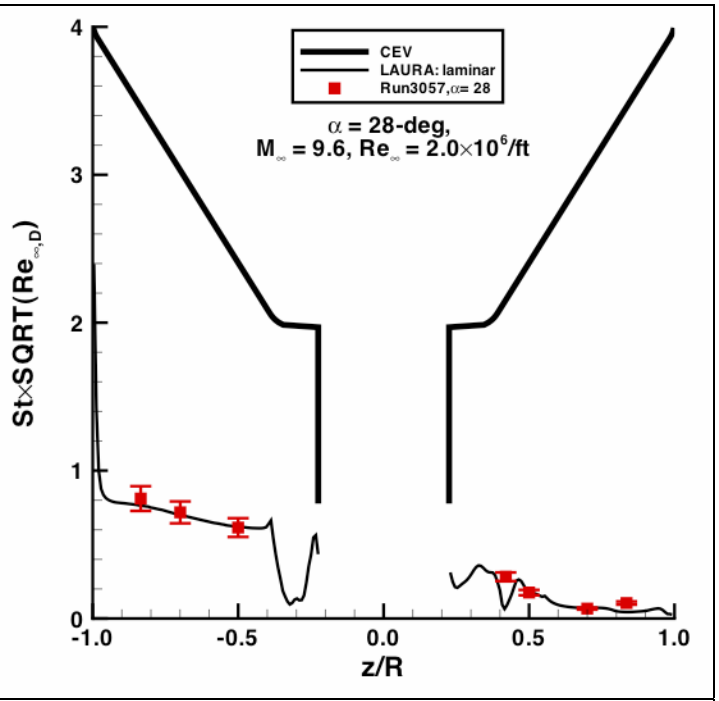

Figure 6 Comparison of wake heating data with predictions, Mach = 10, Re = 2E6/ft, AoA = 28-deg

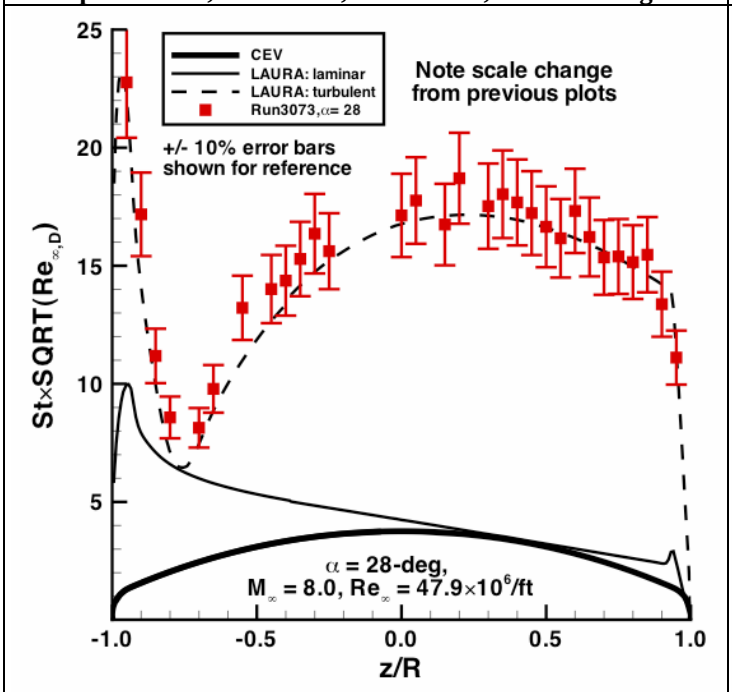

Figure 7. Comparison of forebody heating data with predictions, Mach = 8, Re = 48E6/ft, AoA = 28-deg

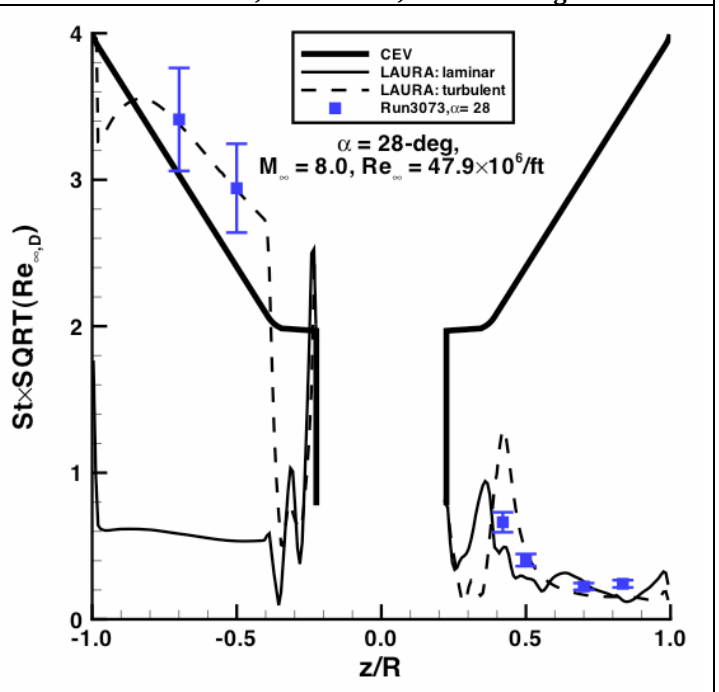

Figure 8. Comparison of wake heating data with predictions, Mach = 8, Re = 48E6/ft, AoA = 28-deg